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# SOIL-RESISTANT TREATMENT FOR AIRCRAFT TACTICAL PAINT SCHEMES

Kenneth G. Clark and David L. Gauntt
Air Vehicle and Crew Systems Technology Department (Code 6062)
NAVAL AIR DEVELOPMENT CENTER
Warminster, PA 18974-5000

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Low-gloss tactical paints continue to pose a significant cleaning problem for fleet activities. Restrictions on pH(7.0 to 10.0), phosphate content (none allowed) and solvent content (less than 32 percent) have limited the effectiveness of exterior cleaning compounds. This project was initiated to investigate soil-resistant treatments that would either prevent the retention of difficult soils or render the paint system more cleanable.

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## CONTENTS

## FIGURES



## TABLES

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## SUMMARY


### INTRODUCTION

Low-gloss tactical paints continue to pose a significant cleaning problem for fleet activities. Restrictions on pH (7.0 to 10 0), phosphate content (none allowed) and solvent content (less than 32 percent) have limited the effectiveness of exterior cleaning compounds. This project was initiated to investigate soil-resistant treatments that would either prevent the retention of difficult soils or render the paint system more cleanable.

### RESULTS

Using colorimeter appearance measurements, a soil-resistant treatment was formulated to improve surface cleanability. A vast improvement in the cleanability of treated surfaces resulted from application of the treatment. For low-gloss tactical paint, repeated applications of the treatment showed significant and constant increases in 60° gloss to a maximum of 9.0 after nine applications and no significant effect on infrared reflectance in the 450-to-2700-nm range. The treatment was not affected by salt spray. $SO_2$/salt spray, silicate ester heat transfer fluid, or JP-5. Minor degradation of the treatment occurred with extensive nonabrasive cleaning, accelerated weathering, tape masking, and mechanical smudging. Cleaners containing particulates (such as MIL-C-85570 Types III and IV) and mechanical scuffing removed the treatment or eliminated its effectiveness. The treatment was not effective on gloss painted surfaces and increased the gloss of the UNICOAT topcoat from 5 to 25. Although a good method for removal of the treatment has not been found, treated surfaces may be repainted without adhesion losses.

### CONCLUSIONS

An effective soil-resistant treatment was developed for low-gloss tactical paint surfaces. The treatment shows good resistance to an aircraft operational environment, with the exception of heavy mechanical abrasion. Several treatments may be applied to tactical paint before gloss increases become significant; however, treatment of UNICOAT painted surfaces is not recommended due to large gloss increases.

### RECOMMENDATIONS

If the NAS Mayport field test is successful, the treatment should be field-tested on "problem areas" of various aircraft. If the treatment is successful for these areas, several test aircraft should be completely treated following a depot repainting. A nonabrasive, noncorrosive remover should be developed for complete removal of the treatment.

## BACKGROUND

Aircraft paint systems perform two functions. First, a paint system protects the underlying metal, plastic, or composite material from degradation by the surrounding environment. Second, a paint system provides the selected appearance for the aircraft. Aircraft exterior appearance is important for several reasons, including visual camouflage, infrared reflectance, and pride in appearance. Much of the unscheduled repainting adds weight to the aircraft, requires valuable maintenance man-hours and coating materials, and adds ozone-generating solvents to the atmosphere. Unauthorized cleaning materials have been used with some success in removing carbonaceous soils, but these are usually high pH products that can cause corrosion and damage polyimide airframe wire insulation.

The effectiveness of authorized cleaning compounds is limited by several factors. The pH range has been restricted to 7.0 to 10.0 to minimize wire insulation degradation. Phosphates have been prohibited to minimize environmental impact. And, limits have been imposed on the concentration of solvents. Materials available under military specification MIL-C-85570 (Cleaning Compound, Aircraft Exterior) are reasonably effective, but usually require the use of special-purpose spot cleaners (Types III and IV). Nevertheless, low-gloss tactical paints continue to pose a significant problem. These paints obtain their low-gloss characteristics from their rough surface topography, which diffuses incident visible radiation. Unfortunately, the valleys and pores in the surface can entrap soils, particularly those soils containing particulate matter such as carbon.

A typical soil on an aircraft surface consists of carbonaceous particles in an organic fluid such as hydraulic fluid or engine oil. Aircraft cleaners, such as those qualified to MIL-C-85570, are specifically designed to remove this type of soil. In fact, a special cleaner (MIL-C-85570, Type IV) for treating smudges, exhaust tracks, and gun blast areas was developed using rubber particles suspended in a matrix of thickened cleaner. When rubbed into the surface, these particles mechanically remove carbonaceous residues without changing the gloss of the paint. Cleaners containing abrasive matter designed for use on gloss paint surfaces (MIL-C-85570, Type III) increase the sheen of aircraft exteriors and reduce the effectiveness of the visual camouflage. Depending on the topography of the paint surface, the type of soil, the conditions under which it impinges on the paint, the prevailing environmental conditions, and the frequency and effectiveness of aircraft washing, soils may become permanently embedded in the paint system.

This project was initiated to investigate soil-resistant treatments that would either prevent the retention of difficult soils or render the paint more cleanable. Much of the success of this effort is due to previous work on the cleanability of aircraft polyurethane topcoats.[1]

## SOIL RESISTANCE EVALUATION METHOD

Soil resistance, as determined in this report, is measured by the cleanability of a surface. When soiled and cleaned using standard procedures (see Appendix A), surfaces with good soil resistance are more effectively cleaned (high cleanability) than those showing poor soil resistance (low cleanability). Cleanability in this study was determined by soiling test panels painted with low-gloss MIL-C-83286 (Coating, Urethane, Aliphatic Isocyanate, for Aerospace Applications) polyurethane paint, conditioning the panels, cleaning the panels using a standard aircraft cleaning compound, and measuring the change in appearance of the panels using the L-value obtained with a colorimeter set up to make measurements in the L-a-b color system. Some of the initial calculations for cleanability were determined using the following equation:

$$\text{Cleanability} \quad (\%) = \frac{L_c - L_s}{L_v - L_s} X\,100 \qquad (1)$$

where $L_v$ is the L-value (which measures lightness) of the virgin surface, $L_s$ is the L-value of the surface after soiling, and $L_c$ is the L-value of the surface after cleaning.

Another method for measuring cleanability is to determine the total color difference in test panel appearance after a standardized soiling and cleaning procedure. In the L-a-b color system, this is done using all three parameters (L, a, and b), measured before soiling and after cleaning. The difference in appearance, calculated as "delta E" in the following equation, accounts not only for changes in L-value (lightness), but also for changes in a-value (red and green) and b-value (blue and yellow).

$$E = [ ( L)^2 + ( a)^2 + ( b)^2]^{1/2} \qquad (2)$$

Surfaces changed significantly by soiling and cleaning have high delta E and poor cleanability. As a rule of thumb, a delta E of less than 1 is usually not detectable with the naked eye.

## FORMULATION OF A SOIL-RESISTANT TREATMENT

The following soil-resistant treatments were evaluated: a fluorocarbon solvent solution (Teflon SBA manufactured by E.I. DuPont de Nemours & Co. (Inc.), Wilmington, DE), an aerosol fluorocarbon release agent (No Cross manufactured by Lectro-Tech, Incorporated, St. Petersburg, FL), and several colloidal silica solutions (Ludox AM, PM, and SM also manufactured by DuPont). Early in this study it was found that when tactical polyurethane paint was treated with the fluorocarbons, the water-base aircraft cleaner (MIL-C-85570, Type II) would not effectively wet the surface. As a result, cleaning efficiency actually decreased. Colloidal silica solutions, on the other hand, provided a barrier that prevented the hydraulic fluid/carbon black soil from becoming embedded and vastly improved the cleanability of the surface.

Two colloidal silicas (Ludox® AM and SM) were chosen for initial study. These materials are solutions of amorphous silica spheres (of diameters 12 and 7 nm, respectively), which have reacted with their alkaline media to produce negative surface charges. The stabilizing counter ion in both products is sodium. However, in the Ludox ® AM, some of the negative surface charges are fixed due to the presence of aluminum atoms in the surface oxide structure (see Figure 1). It was thought that this permanent charge might confer a higher level of durability on the Ludox® Am treatment.

Two soil-resistant treatments were prepared using a DuPont-recommended soil-retardant rug shampoo formulation (see Table 1). To determine the relative durability of the treatments, test panels were treated by applying the formulations (using an eye dropper to completely wet the surface), dried at room temperature for 16 hours, and partially immersed in 10 weight percent sodium hydroxide and 20 weight percent hydrochloric acid. After rinsing in distilled water and drying for 24 hours, the panels were tested for cleanability. Figure 2 also shows single panel cleanability test results, calculated using equation (1), for immersed and dry sections of the test panels.

Table 1. Starting Formulations.
(Concentrations in weight percent)

| FORMULATION | AM | SM |
|---|---|---|
| Merpol$^R$ HCS | 1.5 | 1.5 |
| Duponol$^R$ WAQ | 2.0 | 2.0 |
| Ludox$^R$ AM | 30.0 | |
| Ludox$^R$ SM | | 30.0 |
| Distilled water | 66.5 | 66.5 |

Note: Ludox, Duponol, and Merpol are registered trademarks of E.I. DuPont de Nemours & Co. (Inc.), Wilmington, DE.

It was obvious from this early experiment that the soil resistance of the AM formulation was the better of the two and that it was resistant to strong acid but not strong base. The SM formulation was not especially effective and was affected by both acid and base.

The above formulation was simplified by substituting a 9-mole nonylphenol ethoxylate surfactant for the two surfactants in Table 1. Since, this non-ionic surfactant is available as a military specification product, MIL-D-16791, it was thought that if the Ludox$^R$ AM could be bought for field activities, the treatment could be prepared on-site. Figure 3 shows cleanability results (each result is an average of two determinations) for various Ludox$^R$ concentrations and Ludox$^R$/surfactant (L/S) ratios. Results for the recommended DuPont rug shampoo formulation at various dilutions are represented by the first L/S ratio of 8.57. Results for four additional formulations, prepared by substituting MIL-D-16791 for the two DuPont surfactants, are represented by the remaining L/S ratios. The 15 percent Ludox$^R$ concentration appeared to give generally higher cleanability results, and this was used in later studies. Although an L/S ratio of 30 (indicating a 0.5 percent surfactant concentration) appeared to be optimal for soil resistance, a 1.0 percent surfactant concentration was chosen so that the final formulation would also be potent enough to act as a mild wipe-on-wipe-off cleaner. Further studies, therefore, involved the formulation in Table 2.

Table 2. Soil-resistant Treatment Formulation.
(Concentrations in weight percent)

| | |
|---|---|
| Ludox$^R$ AM | 15.0 |
| Distilled water | 84.0 |
| MIL-D-16791 | 1.0 |

Later in this study Ludox$^R$ PM was also evaluated but proved to be inferior to the Ludox$^R$ AM in soil resistance during repeated cleaning.

To determine whether pH would influence the soil resistance of the treatment, the treatment as formulated in Table 2 was modified by adjusting pH with hydrochloric acid or sodium hydroxide solutions to obtain treatments ranging in pH from 3.5 to 10.5. Cleanability results (each result is an average of two determinations) are shown in Figure 4. Since pH does not influence these soil resistance tests, further studies will utilize the formulation listed in Table 2 without adjustment of pH. As formulated, the normal pH of this treatment is 9.6.

## APPLICATION OF THE TREATMENT

Initially, two methods were evaluated for applying the treatment. In Method 1, the treatment solution was applied by pipette to the top of a 2.5-by-inch test panel, inclined at a 60° angle to the horizontal. Enough solution was applied to run down and off the panel, giving uniform coverage with no bubbles. Test panels were then dried at room temperature for 16 hours. When large bubbles were inadvertently produced on the surface, subsequent soiling and cleaning resulted in a spotty appearance.

In Method 2, the treatment solution was applied as in the first but then rinsed immediately with distilled water and dried. Cleanability results were clearly inferior: with the first method 97.4 percent and with the second 88.6 percent. In addition to the decrease in cleanability, panels appeared very streaky after soiling and cleaning.

For the remainder of the laboratory soil-resistant treatment evaluation, Method 1 was used to prepare test panels. In the later service test on the trailing edges of a P-3, the treatment was applied by spraying at approximately 20 psig. Spraying proved very effective in creating a thin, uniform film without unwanted bubble formation.

## EFFECT OF THE TREATMENT ON PAINT CAMOUFLAGE CHARACTERISTICS

One of the initial concerns for tactical paint schemes was the effect of the treatment on camouflage characteristics. The low gloss requirement of the gunship quality MIL-C-83286 polyurethane topcoat is important for achieving the visual camouflage appearance. Abrasive materials, such as cleaners or abrasive mats, are forbidden on these paint systems since they tend to increase the gloss of the paint. Higher paint glosses provide more specular reflectance, increasing detectability and. therefore. increasing vulnerability. Although the gray camouflage schemes used by Navy aircraft do not possess the low infrared (IR) reflectance values of the field green MIL-C-85285 paint used by Marine helicopters, increased IR reflectance could be a potential problem.

To determine the effect on gloss, the treatment was applied to a test panel painted with MIL-C-83286 (Color No. 36495) and air-dried for 30 minutes. After obtaining the 60° gloss and the near-infrared spectrogram, the treatment was reapplied and dried as before. This process was repeated nine times to define a worst case situation. Results are shown in Figure 5. In general, the infrared reflectance over the 450-to-2700-nm range was virtually unchanged (see Figure 6), with a minor decrease in the reflectance at 2700 nm. Gloss, however, did show significant and constant increases with each application. Since the surfactant could have contributed to the increase in gloss, the gloss study was repeated using an intermediate rinse following the drying step. Results are shown in Figure 6. The gloss and IR reflectance results were essentially the same as before. Surprisingly, the gloss reached a maximum after 10 applications.

In the later field test on a P-3 aircraft (BUNO 148889), gloss increases were also noted. For the area painted with MIL-C-83286 (Color No. 36375), the gloss increased from about 1.2 to 1.3. But, for the area painted with the new experimental UNICOAT (Color No. 36375), the gloss increased from about 5.0 to 25. The initially higher gloss of the UNICOAT surfaces probably indicates a more level topography, while that of the gunship quality MIL-C-83286 is extremely rough. Since the diameter of the silica particles in Ludox$^{R}$ AM is only 12 nm, it is doubtful that the increase in gloss comes from changes in the general topography.

## EVALUATION OF THE TREATMENT

Effectiveness in a service environment was studied by exposing the treatment to a number of different conditions. To date, the following have been investigated:

- Repeated cleaning with MIL-C-85570 Type II
- Cleaning with other MIL-C-85570 products
- Colored cations in water supplies
- Salt spray exposure
- $SO_2$/salt spray exposure
- Accelerated weathering
- Coolanol 25 R and jet fuel JP-5
- Paint drying time
- Two different polyurethane topcoats
- UNICOAT topcoat
- Mechanical effects
- Repainting
- Application to gloss painted surfaces
- Removal of the treatment

In these studies, soil resistance was determined using "delta E," which is a measure of the difference in appearance between the untreated surface and the treated surface after soiling and cleaning. Obviously, a small delta E is good; a large delta E is not.

Test panels were painted with MIL-C-83286 polyurethane paint (Color No. 36495), air-dried for 7 days, then heated in an oven at 150°F for 7 days. No further conditioning of panels was used. All test panels, with the exception of those used in the comparison of the two different polyurethanes (Color No. 36320), had 60° glosses and 2.0 and 2.3.

Treatments were applied using Method 1. Test panels were dried for at least 30 minutes prior to exposure to the various conditions (e.g., JP-5, salt spray, solutions of various cations). After rinsing and drying at room temperature, the test panels were tested for cleanability (soil resistance) using the method described in Appendix A.

REPEATED CLEANING WITH MIL-C-85570 TYPE II

To estimate the durability of the treatment, treated and untreated test panels (in triplicate) were repeatedly soiled, cleaned, and measured by a colorimeter. Figure 8 shows the delta E results. Formula AM was the formulation developed above; Formula PM was an inferior formulation made with Ludox[R] PM. The panel treated with Formula AM shows excellent soil resistance, while the untreated panel shows a rapid accumulation of residual soil.

CLEANING WITH OTHER MIL-C-85570 PRODUCTS

To identify cleaners that cause degradation of the treatment, single test panels were treated and repeatedly cleaned with a specific cleaner type under MIL-C-85570:

| | |
|---|---|
| Type I | General-purpose exterior aircraft cleaner (maximum solvent content = 32 percent; contains aromatic hydrocarbons) |
| Type II | General-purpose exterior aircraft cleaner (maximum solvent content = 15 percent; aromatic hydrocarbons prohibited) |
| Type III | Abrasive spot cleaner for gloss painted surfaces |
| Type IV | Rubberized spot cleaner for tactical paint surfaces |

Type V Gel-type degreaser for wheel wells

Cleaning was performed on the Gardner Heavy Duty Wear Tester as specified in Appendix A, but using 100 back-and-forth strokes in one direction followed by 100 back-and-forth strokes in the 90° direction (equivalent to 20 normal cleaning cycles in the specification). After rinsing and drying, panels were soiled and cleaned as in previous tests to determine soil resistance. Results, shown in Figure 9, indicate that the two spot cleaners (Type III and Type IV) are significantly more damaging to the treatment. Type II appears to be the mildest cleaning material, with Types I and V only slightly more damaging. No direct correlation with actual field cleaning operations has been established. In some aircraft wash operations, a single pass with a cleaning pad is common; in those cases, 200 back-and-forth strokes might translate to 200 washes or over 7 years of cleaning (at one wash every 2 weeks, as prescribed by reference 2.

Colored Cations in Water Supplies

Since the dried treatment had some similarity to cation exchange media, it was thought that colored cations in wash rack water supplies (such as iron or copper) might be held preferentially, discoloring the treatment. To check this phenomenon, single treated test panels were measured by a colorimeter, immersed for 5 minutes in 5 weight percent solutions of various compounds. After rinsing and drying, panels were soiled, cleaned, and measured again to determine a delta E. Results, shown in Figure 10, show that this type of discoloration is possible with iron(III) causing the most significant change. This delta E, however, is still well below those values observed for untreated surfaces that have been soiled and cleaned.

## SALT SPRAY AND $SO_2$ SALT SPRAY EXPOSURE

The durability of the treatment in a salt fog environment was evaluated by treating the test panels, then exposing them in a 5-percent salt-fog chamber with parameters set in accordance with American Society for Testing and Materials (ASTM) Method B117 and G85 and with the panels inclined at 15° from vertical. After exposure, the panels were removed rinsed, dried, soiled, and cleaned to determine soil resistance. Results for duplicate panels, shown in Figures 11 and 12, indicate no apparent loss of treatment effectiveness. Untreated test panels exposed in $SO_2$/salt spray exhibited an unexplained increase in soil resistance.

## ACCELERATED WEATHERING

In contrast to salt spray exposure, treated test panels exposed in a xenon are accelerated weathering chamber appeared to lose some of their soil resistance. Duplicate results shown in Figure 13 show a slight loss in soil resistance with increasing exposure. However, these results are still superior to those of unweathered, untreated test panels.

## COOLANOL 25R AND JET FUEL JP-5

To determine the effect of two common aircraft fluids, a silicate ester heat transfer fluid (Coolanol 25R) and jet fuel (JP-5), single test panels were treated, then soaked for 16 hours in each of the fluids. After the panels were removed, cleaned, and dried, they were soiled and cleaned to measure soil resistance. In Figure 14, comparison with unexposed panels indicates no significant change in soil resistance.

## PAINT DRYING TIME

To determine the optimum drying time for MIL-C-83286 polyurethane paint prior to application of the soil-resistant treatment, the test panels were painted and single panels periodically treated. One set of panels was cleaned prior to treatment. A second set was not cleaned. After treatment, panels were soiled and cleaned to determine soil resistance. The results, shown in Figure 15, indicate that freshly painted surfaces can be treated after 3 days of drying at room temperature (approximately 70°F) and that cleaning prior to treatment may not be necessary.

## TWO DIFFERENT POLYURETHANE TOPCOATS

Test panels used in each of the above studies were painted with MIL-C-83286 (Color No. 36495) and exhibited 60° gloss readings of 2.0 to 2.3. For comparison, soil resistances were determined for single, untreated panels and triplicate treated panels painted with MIL-C-83286 (Color No. 36320) as manufactured by two different vendors. Results, shown in Figure 16, indicate fair soil resistance for the higher gloss paint without treatment and excellent soil resistance with treatment. The lower gloss paint exhibited poor soil resistance without treatment and only fair soil resistance with treatment.

## UNICOAT TOPCOAT

The experimental primer/topcoat paint, known as UNICOAT, was also checked for soil resistance both with and without the treatment. No difference was apparent. In both cases, the UNICOAT paint exhibited good soil resistance. In a later field test, it was noted that treated UNICOAT surfaces increased in gloss from about 5 to about 25.

## MECHANICAL EFFECTS

To determine the potential harm caused by mechanical effects, a treated test panel was masked and stripped using MIL-T-21595 masking tape, a second panel was smudged with finger pressure, and a third panel was scuffed with black rubber. Panels were then soiled and cleaned and measured by a colorimeter to determine soil resistance. Somewhat lower soil resistances were noted for areas that were masked and smudged. Rubber scuff marks could not be removed from either treated or untreated areas.

## REPAINTING

To ensure that the treatment could be refinished with topcoat if necessary, a treated surface was cleaned using MIL-C-85570 Type II cleaner, and a MIL-C-83286 polyurethane topcoat was spray applied. A wet tape test, performed after the normal 7-day drying time, indicated excellent adhesion.

## APPLICATION TO GLOSS-PAINTED SURFACES

When the treatment was applied to surfaces painted with MIL-C-83286 gloss white, soiling and cleaning resulted in a streaky appearance. Further work with gloss surfaces was discontinued due to the ease with which they are normally cleaned.

## REMOVAL OF THE TREATMENT

Strong caustic solutions and abrasive cleaning compounds are effective in removing the treatment, but caustics can cause aluminum corrosion and abrasives increase the gloss of the underlying gunship quality paint. However, the treatment can be oversprayed with a new polyurethane topcoat, if it becomes objectional. Further work is being done to find a more suitable alternative.

## FIELD TEST RESULTS

The treatment, recently named "TACSHIELD," has been applied to sections of a P-3 wing trailing edge just aft of the inboard engine exhausts. The left side, painted with UNICOAT, exhibited a drastic increase in gloss after treatment (from about 5 to about 25). The right side, painted with MIL-C-83286 (Color No. 36375 Gunship quality), showed only minor differences in soil resistance, but the side painted with the tactical gunship quality paint showed a very marked difference: in treated areas, exhaust residues could be removed easily with the MIL-C-85570 Type II cleaner; in untreated areas, exhaust soils were embedded in the paint and could not be removed. For more details and photographs, see Appendix B.

A second field test was initiated at NAS Mayport, where selected "problem areas" of an SH-60 aircraft were treated. Results are not yet available.

## CONCLUSIONS

An effective soil-resistant treatment was developed for low-gloss, tactical paint surfaces. Even after repeated cleaning with MIL-C-85570 Type II exterior aircraft cleaner, the treatment provides excellent soil resistance. Laboratory tests have shown that salt spray with and without sulfur dioxide, fuel, hydraulic fluid, coolant, non-abrasive cleaners, and strong acid have little or no effect on the durability of the treatment. Accelerated weathering tests have produced some degradation of the treatment and some cations, such as iron, can produce some minor changes in color. The actual effect of weathering and water quality on a treated surface are probably insignificant compared with the poor soil-resistance characteristics of untreated surface.

The effect of the treatment on the gloss of gunship quality paints, those with a gloss of less than 3.0, is expected to be minimal even for several treatments. However, paints with higher glosses will require additional study. The treatment should not be used on UNICOAT painted surfaces, if it is important to maintain a 60° gloss of less than 25.

Field tests will be required to determine the extent to which the treatment could be used on aircraft painted with tactical paint and the life expectancy of the treatment.

## RECOMMENDATIONS

If the NAS Mayport field test for the SH-60 proves successful, additional field tests should be arranged using TACSHIELD on "problem areas" of other aircraft. Areas where hand smudges, fingerprints, boot marks, exhaust tracks, and gun blast and hydraulic fluid discoloration normally appear would be excellent test ares for the treatment. Whether this treatment will be used for entire aircraft depends on the success for such area. If the treatment is only mildly successful, application to the entire aircraft might result in greater contrast between problem spots and the rest of the exterior surface. If the treatment is very successful for specific areas, several test aircraft should be completely treated following a depot repainting. In all field tests the treatment should be monitored to determine its useful life.

A noncorrosive, nonabrasive remover for TACSHIELD should be developed. A high-pH remover, such as a silicate-inhibited caustic, should not be authorized for routine use due to the potential corrosion and damage to polyimide insulated wiring. However, such a material may be useful on a limited basis.

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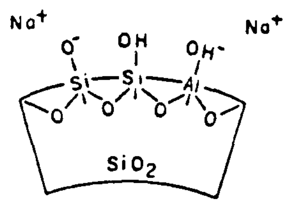
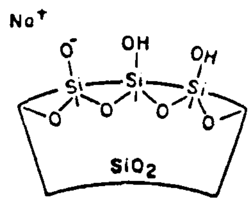
2. NAVAIR 01-1A-509, "Aircraft Weapons System Cleaning and Corrosion Control," 1 July 1988




Ludox[R] AM




Ludox[R] SM

Figure 1. Chemical Structure of Ludox[R] Silicas.

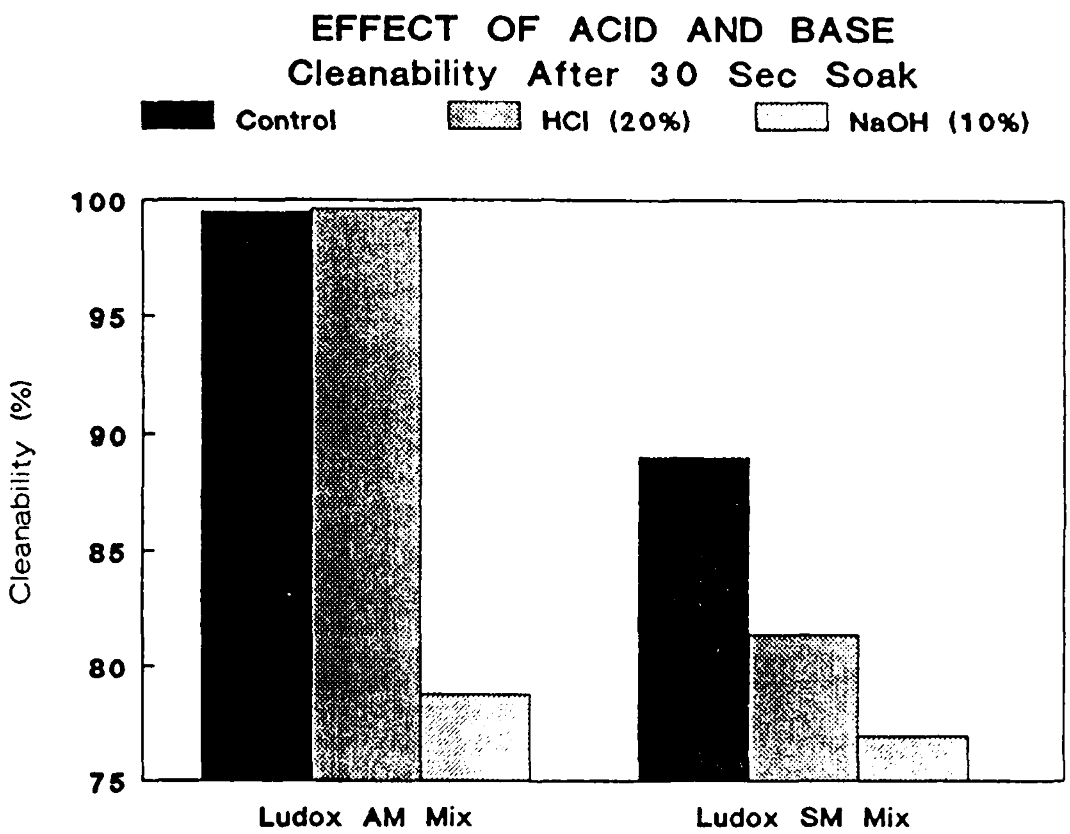



Figure 2. Effect of Acid and Base.

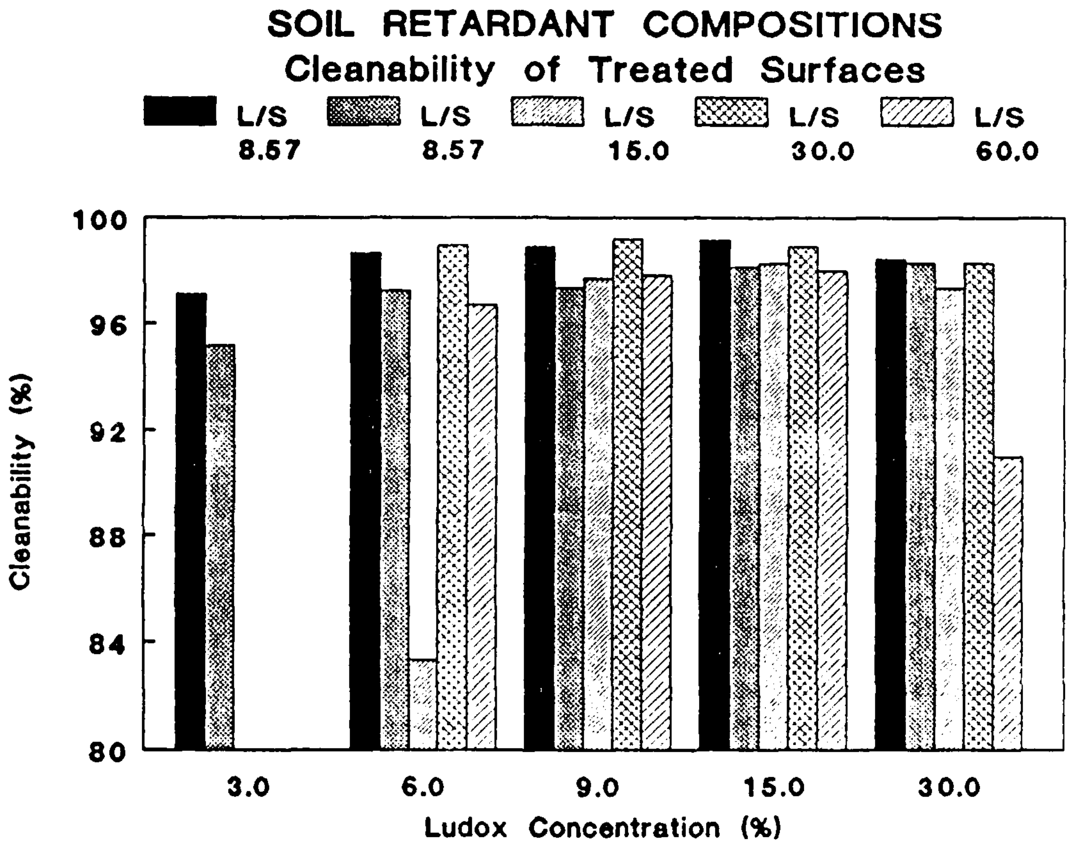



Figure 3. Soil-Retardant Compositions.

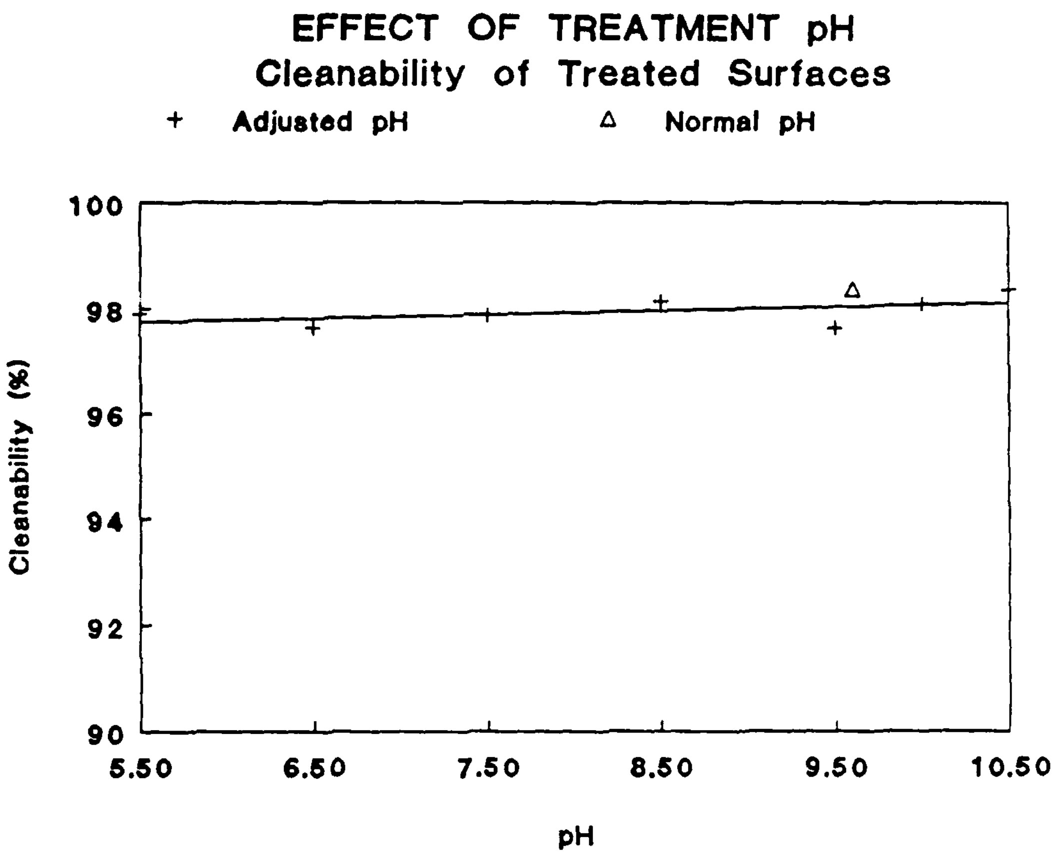



Figure 4. Effect of Treatment pH.

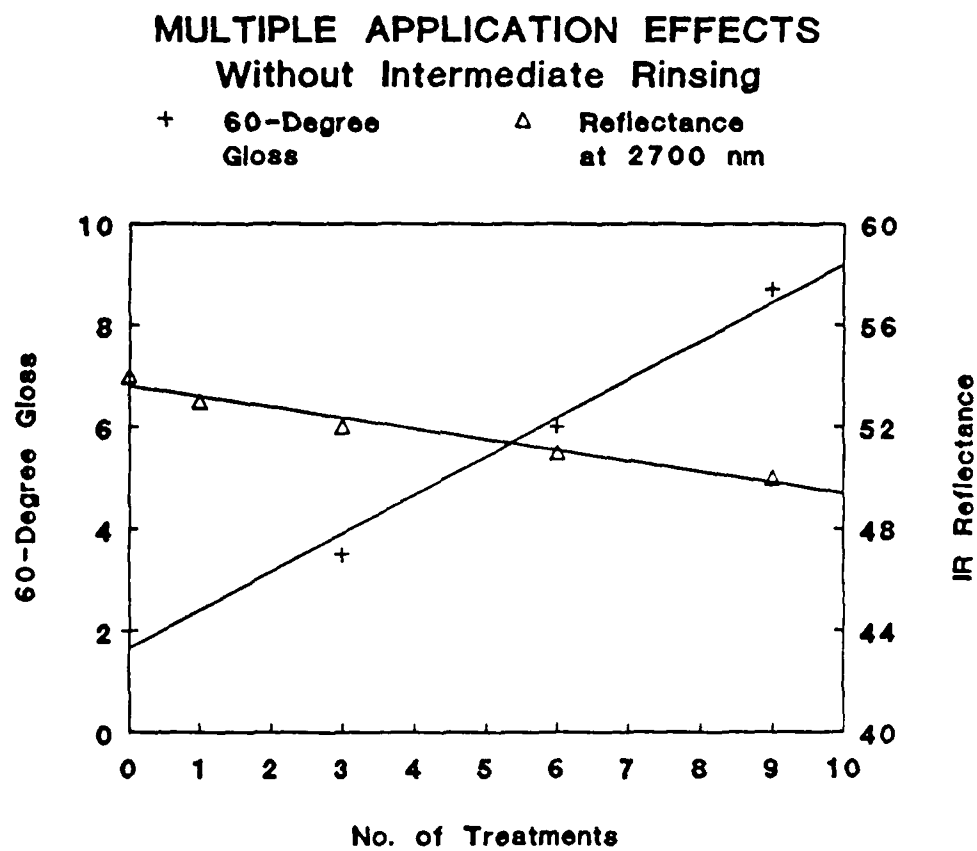



Figure 5. Multiple Application Effects Wighout Rinsing.

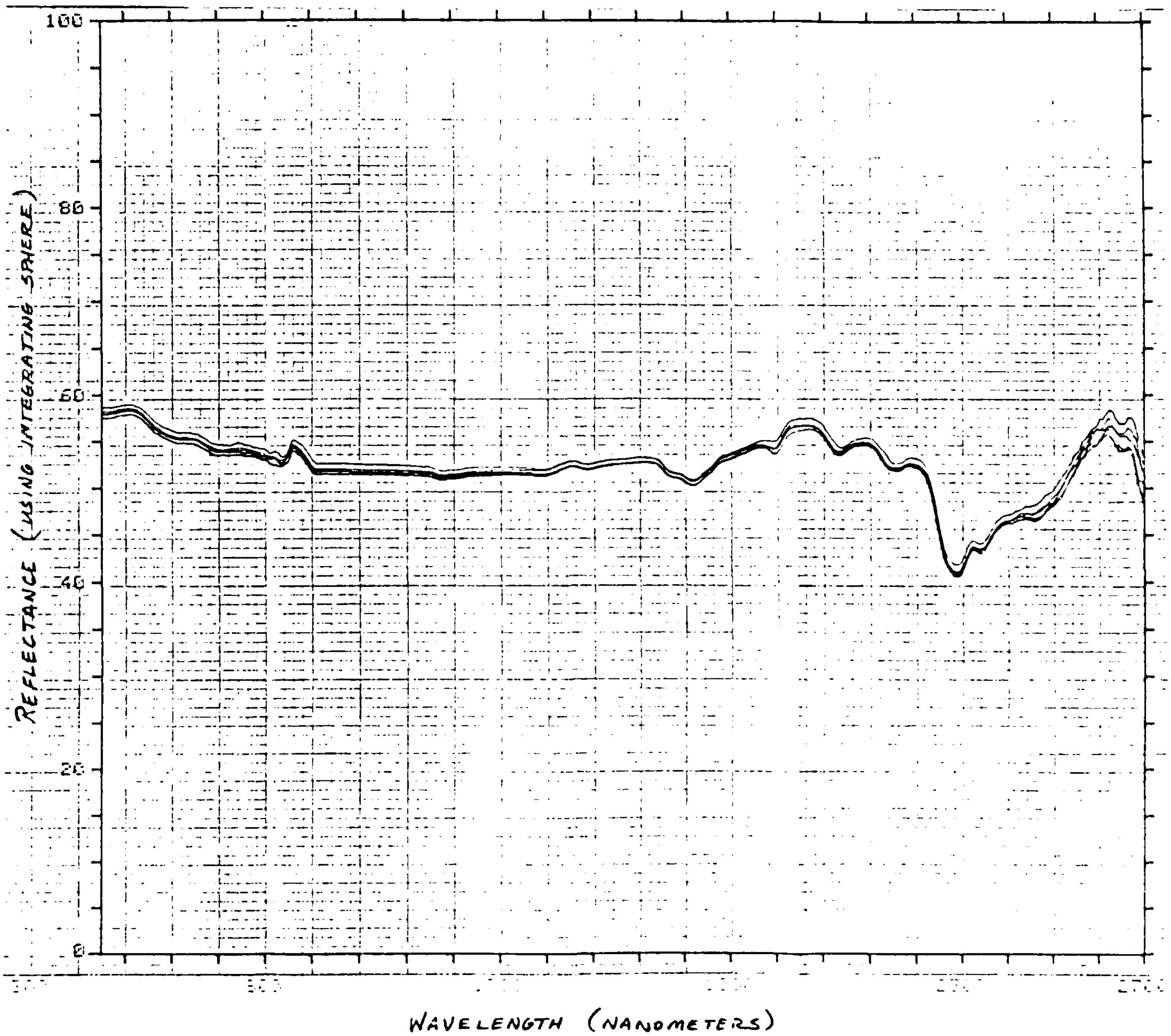



Figure 6. Near IR Reflectance Spectrogram for Treated Surfaces.

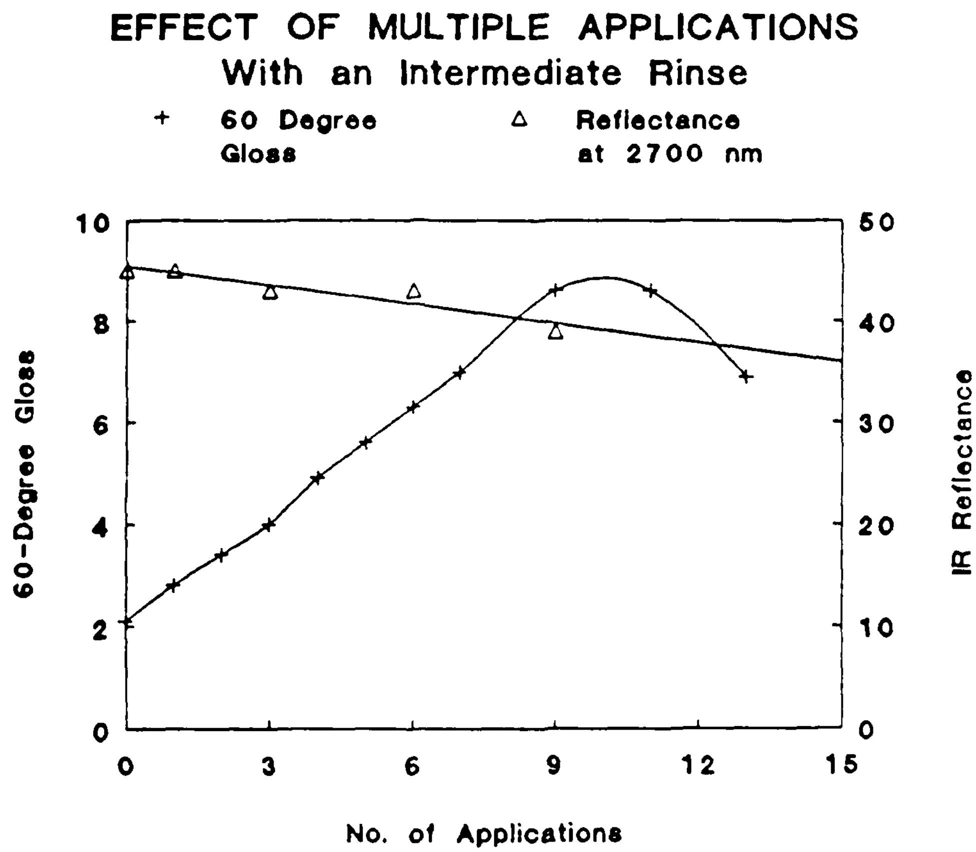



Figure 7. Multiple Application Effects with Rinsing

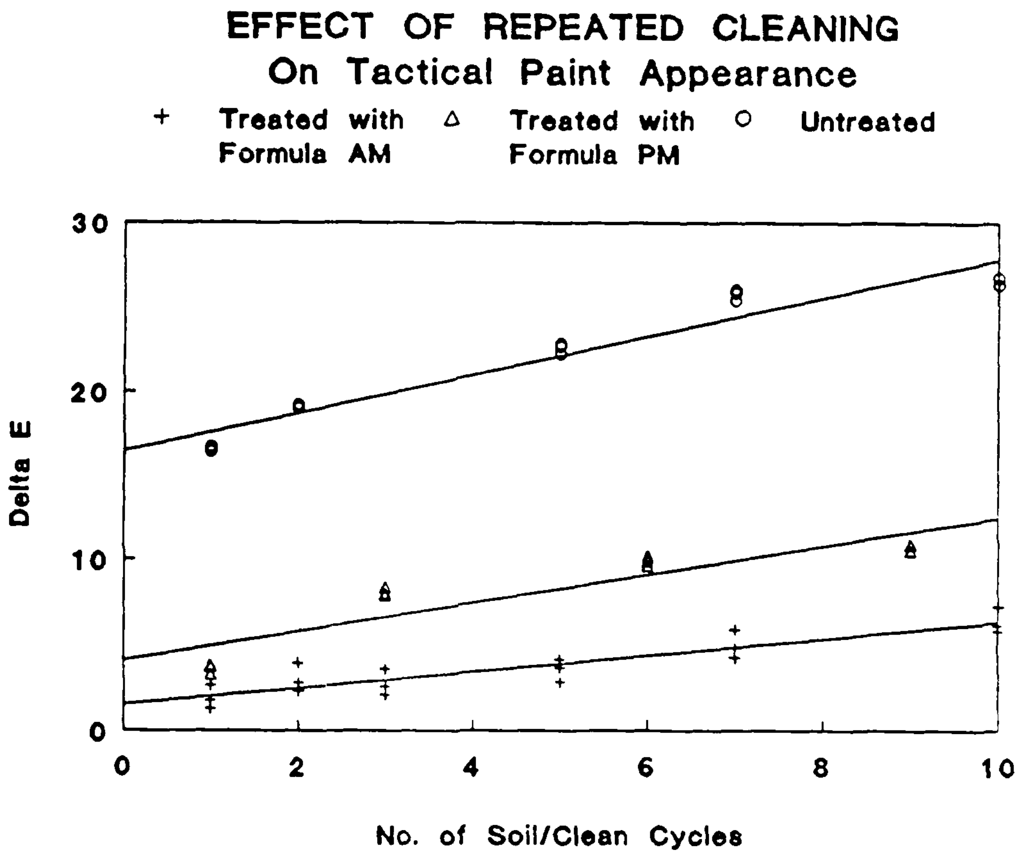



Figure 8. Effect of Repeated Cleaning

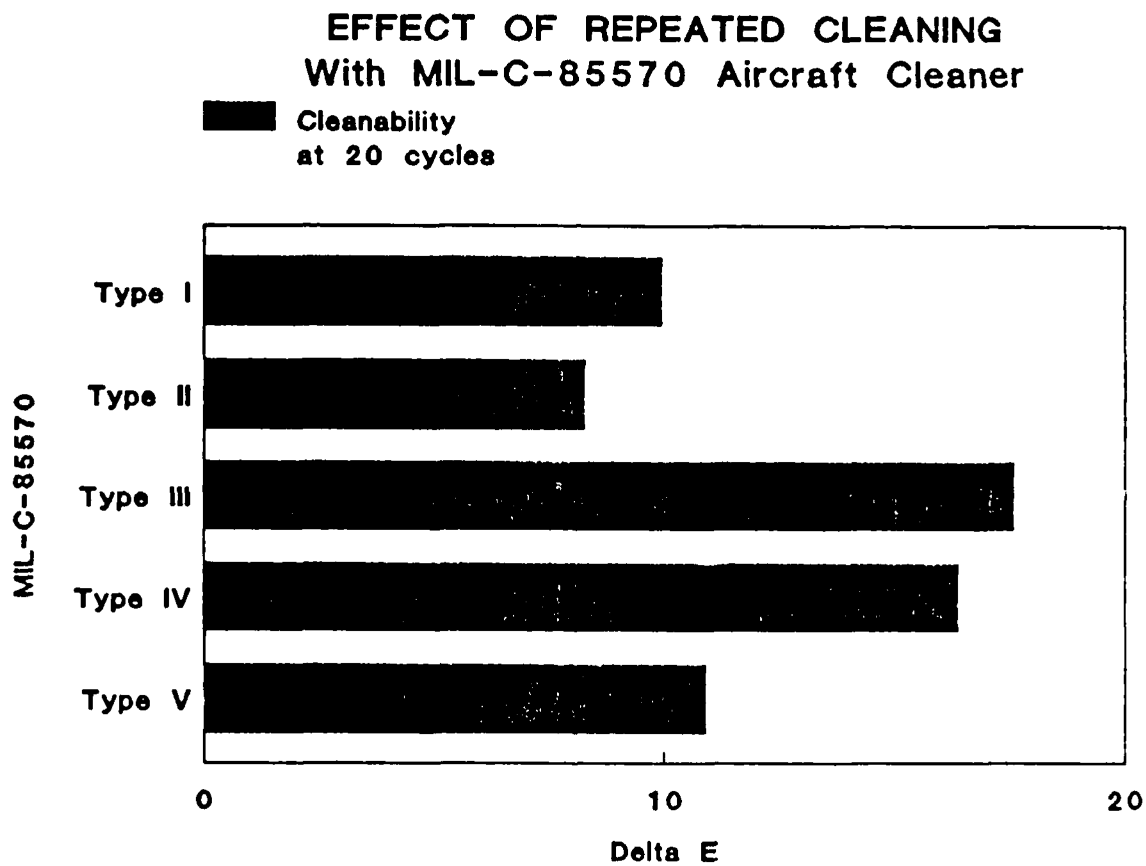



Figure 9. Effect of Repeated Cleaning With Other Cleaner Types.

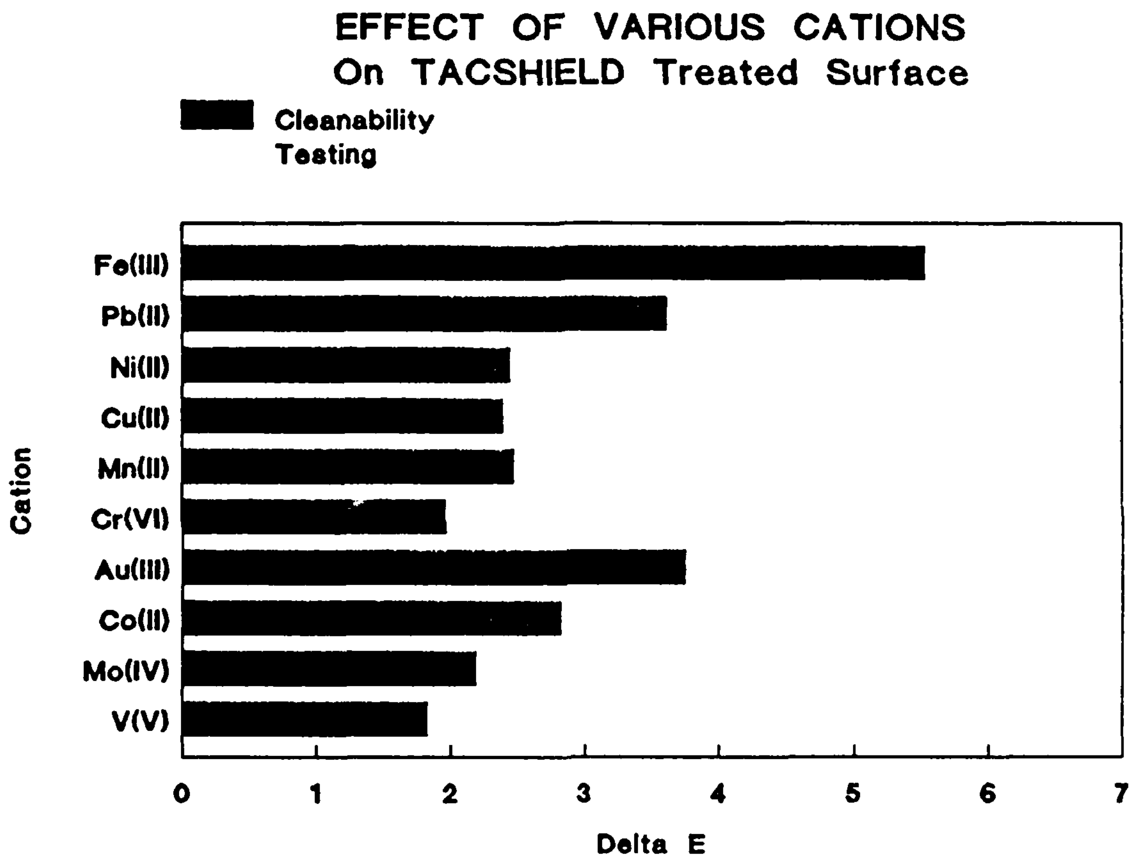



Figure 10. Effect of Various Cations.

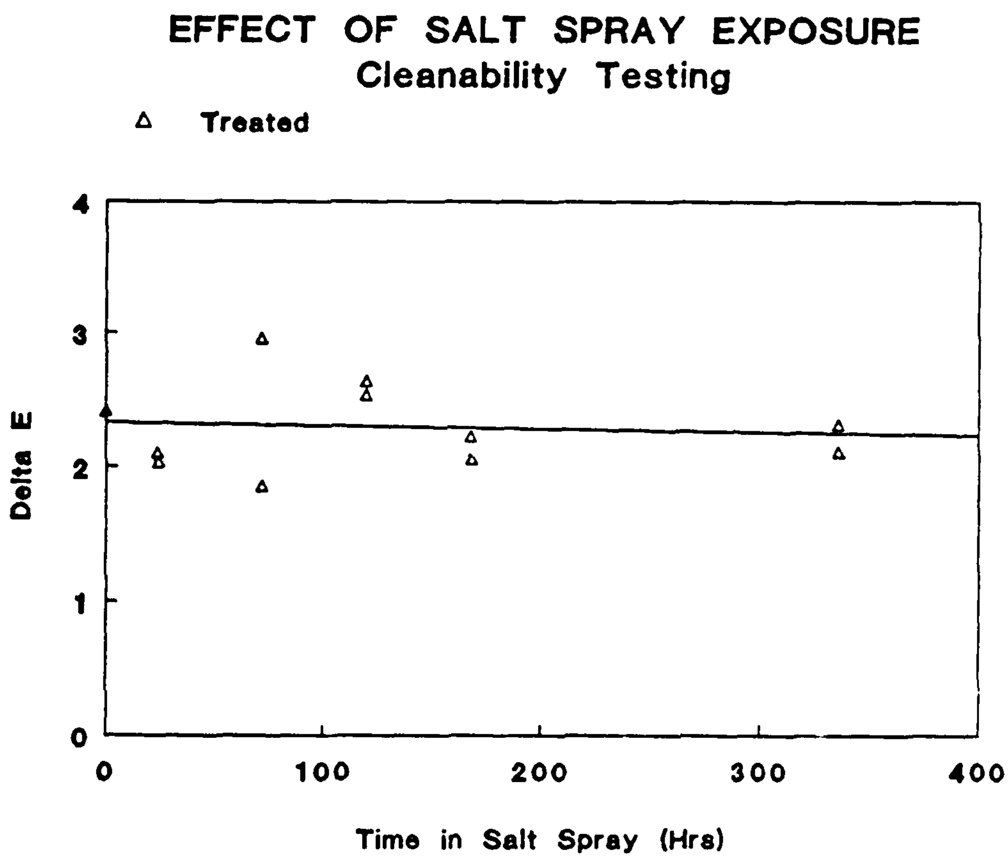



Figure 11. Effect of Salt Spray Exposure.

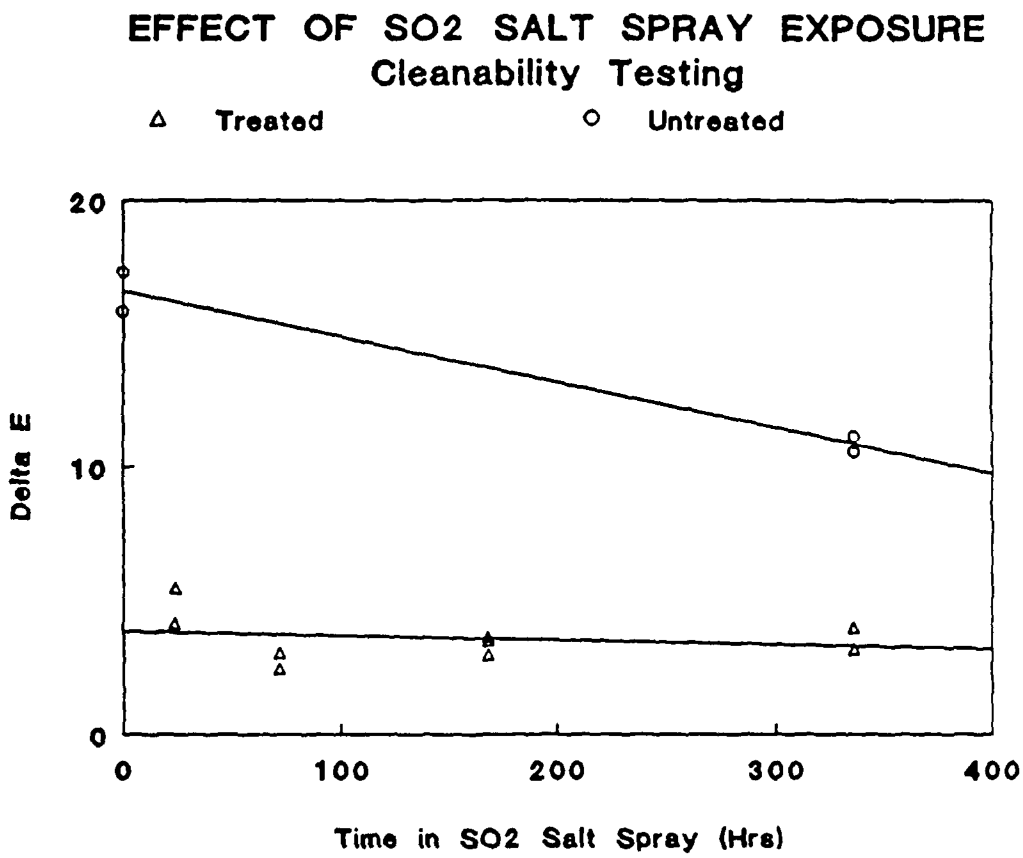



Figure 12. Effect of $SO_2$/Salt Spray Exposure.

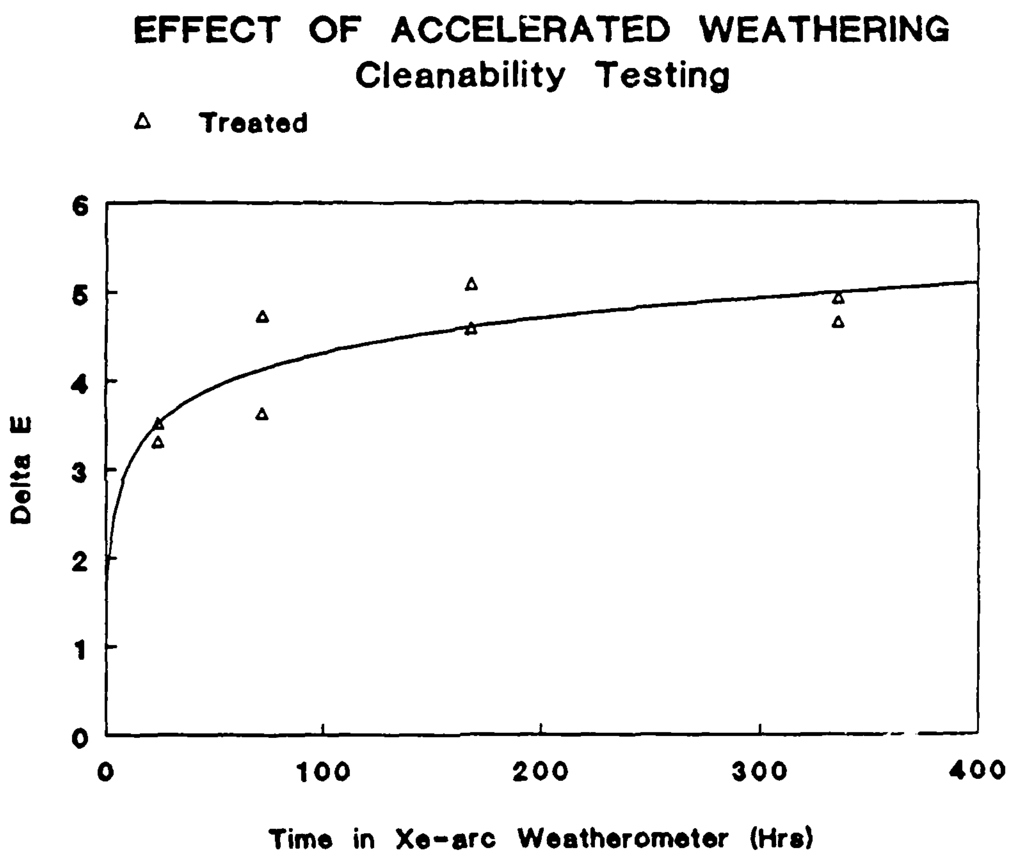



Figure 13. Effect of Accelerated Weathering.

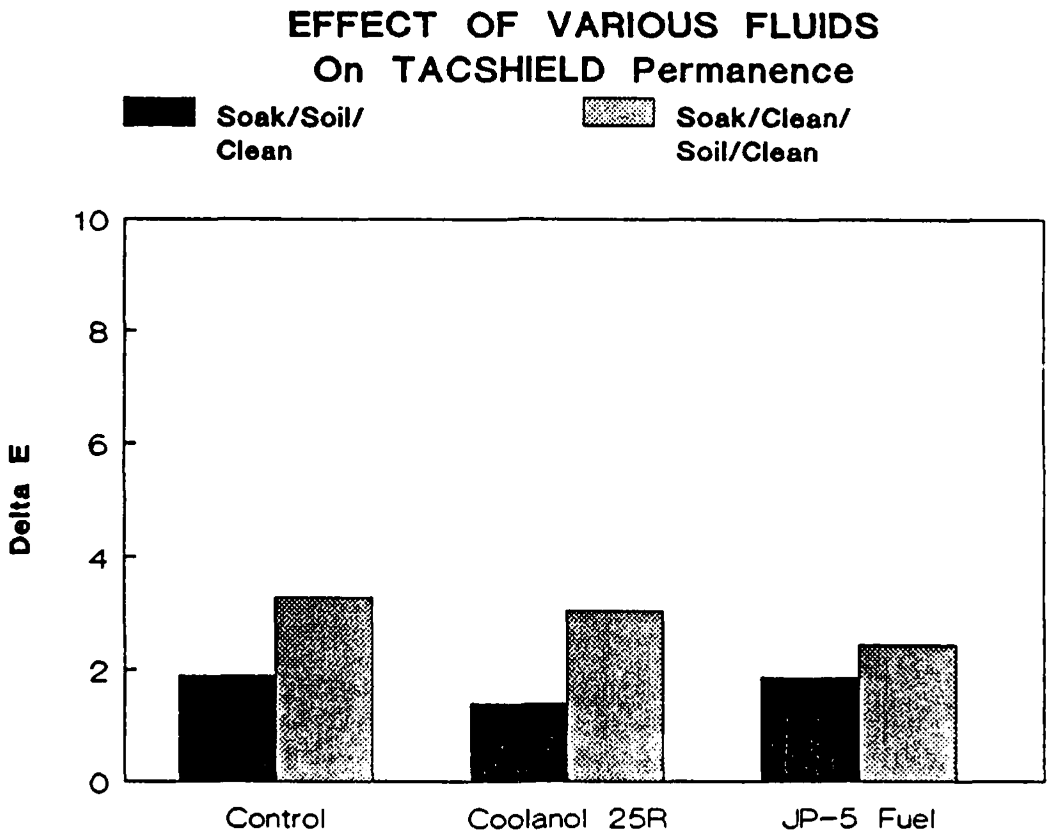



Figure 14. Effect of Various Fluids.

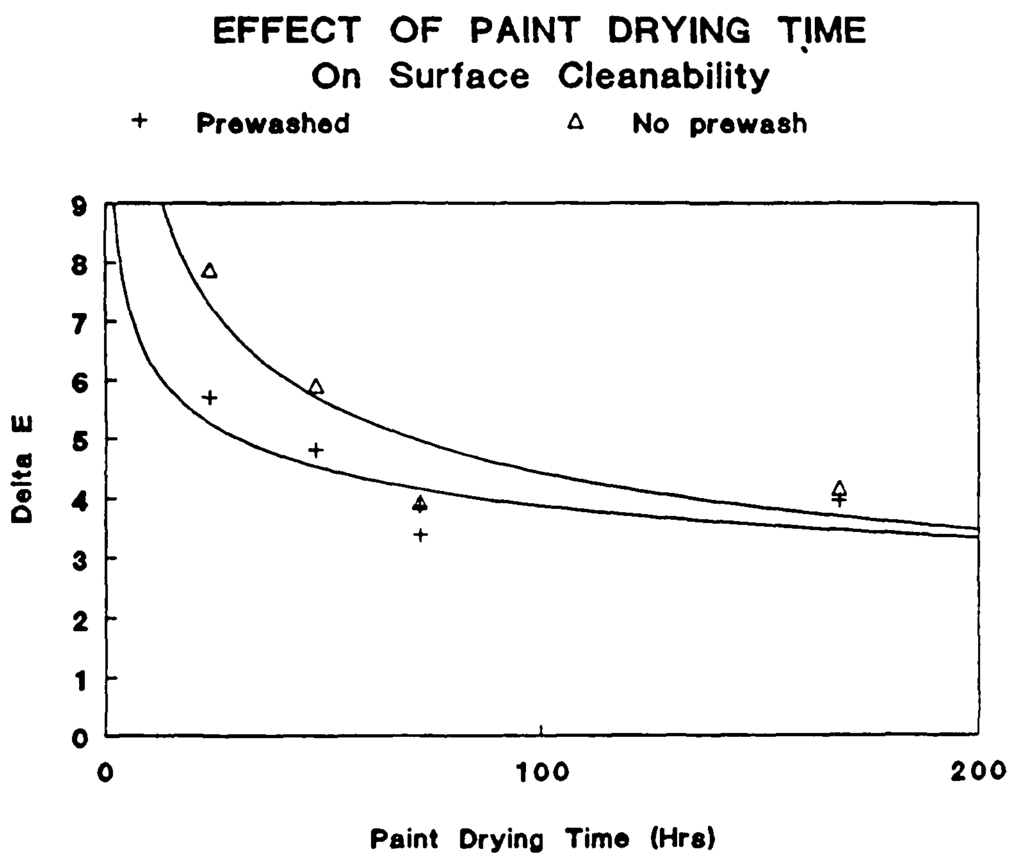



Figure 15. Effect of Paint Drying Time.

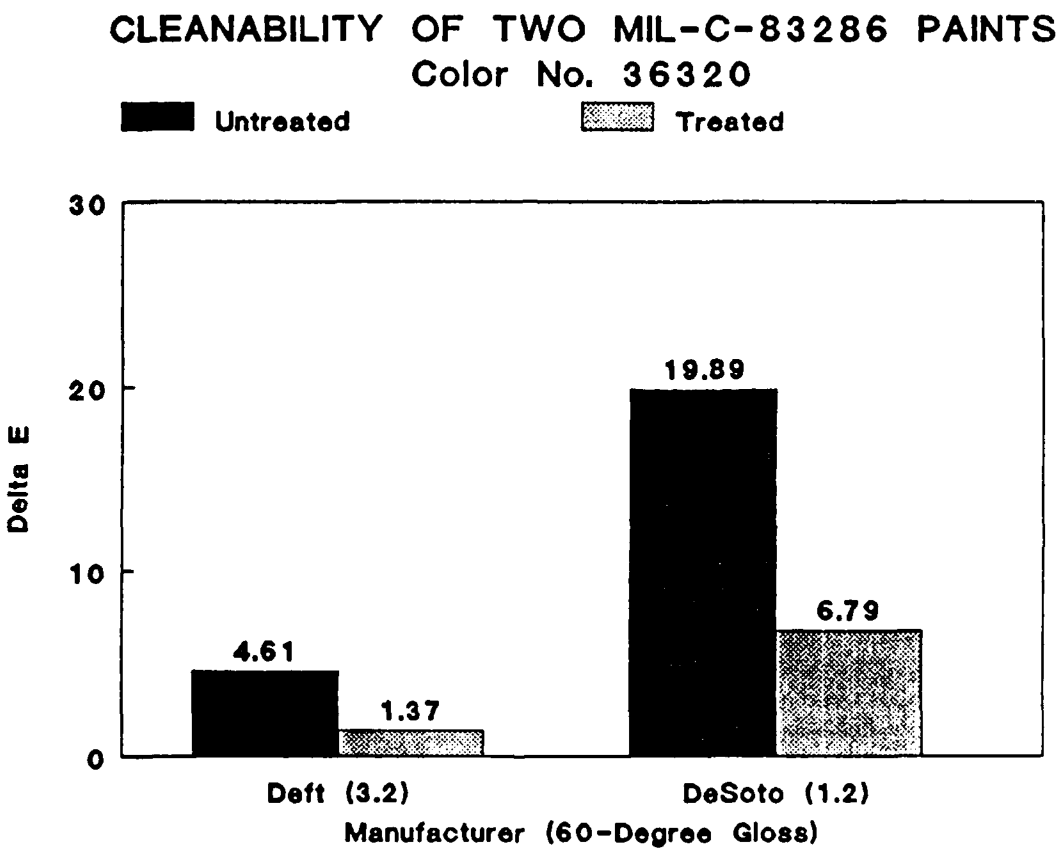



Figure 16. Cleanability of Two MIL-C-83286 Paints.

# APPENDIX A

## CLEANABILITY OF PAINTED SURFACES

# CLEANABILITY OF PAINTED SURFACES

This method is the laboratory procedure used in this work to evaluate soil resistance and is similar to the method used in reference 1.

## 1.0 Apparatus

1.1 Test panels 3 X 6 X 0.02 inches (7.6 X 15.2 X 0.05 cm), cut from 2024-T3 aluminum alloy, chromate conversion coated with materials conforming to MIL-C-81706 to produce a coating meeting the requirements of MIL-C-5541.

1.2 One-quart (l L), wide-mouth, glass jar.

1.3 Balance accurate to 0.1.g.

1.4 High-shear mixer.

1.5 Hog-bristle brush (Gardner WG-2000-B)

1.6 Acid brush.

1.7 Rubber roller, 5.0 ± 0.1 lbs (2270 ±50 grams).

1.8 Forced-draft oven, capable of 221 ±4°F (105) ±2°C).

1.9 Wear tester (Gardner Heavy Duty Wear Tester).

1.10 Template for positioning panels on wear tester at ±45° to the cleaning stroke.

1.11 Cellulose sponge backed with nylon web (Scotch Brite 63).

1.12 Colorimeter, suitable for measurement in the L-a-b color system (MacBeth Model MC-1010 S).

## 2.0 Preparation of Soil

2.1 Place 50.0 ±0.5 g carbon black (such as Raven 1040, manufactured by Columbian Chemical Company) and 500 ±1 g MIL-H-83282 hydraulic fluid.

2.2 Homogenize the above mixture using a high shear mixer for 15 ±1 min. Prior to application of the soil to the test specimen, thoroughly stir or shake the mixture.

## 3.0 Preparation of the Control Formula Cleaner

3.1 The following is a control formula for MIL-C-85570, Type II aircraft cleaner as listed in paragraph 4.6.13.1 of the specification.

3.2 Mix the first five ingredients listed below, then neutralize the mixture to a pH of 8.0 with acetic acid. Add the remaining ingredients and mix until homogeneous.

| | |
|---|---|
| Igepal CO-630 (Note 1) | 10.0 |
| Monamid 150CW (Note 2) | 5.0 |
| Dipropylene glycol methyl ether | 10.0 |
| Deionized water | 71.5 |
| Benzotriazole | 0.5 |
| Hostacor 2098 (Note 3) | 2.0 |
| Morpholine | 1.0 |
| | 100.0 |

(1) GAF Corporation or equivalent
(2) Mona Industries, Inc. or equivalent
(3) American Hoechst Corp. or equivalent

4.0 Preparation of Test Panels

4.1 To the aluminum test specimens described in 1.1, apply MIL-P-23377 epoxy primer to a thickness of 0.6 to 0.9 mils (15 to 23 um). Allow to dry for 1 hour at ambient laboratory conditions. Apply the desired topcoat to the intended thickness. For MIL-C-83286 polyurethane, mix the two components and allow a 30-min dwell time. Apply the paint to a thickness of 1.8 to 2.2 mils (46 to 56 um) and allow the coating to cure for 1 week at room temperature, then bake the coated panels at 150 ±4°F (66 ±2°C) for 1 week.

4.2 If determining percent cleanability, measure the L-value of the virgin surface ($L_v$). If determining the total color difference between the virgin and the soiled and cleaned surface, measure the L, a, and b-values for the virgin surface ($L_v$, $a_v$, and $b_v$).

4.3 After allowing the desired cure time and conditions, use an acid brush to coat the painted surface of a test panel with the soil described in 2.0. Remove excess soil by covering the test panel with absorbent tissue and exerting pressure by rolling the tissue with the rubber roller. Repeat this blotting procedure three times using fresh tissue each time. Brush the soiled surface 10 times in one direction only, parallel to the long dimension of the test panel, using the hog bristle brush. Bake the test panel at 221 ±4°F (105 ±2°C) for 60 ±1 min.

4.4 If determining percent cleanability, measure the L-value of the soiled surface ($L_s$).

5.0 Cleaning Procedure

5.1 Dilute one part of the control formula with nine parts distilled water (by volume).

5.2 Clean the test panel using the wear tester as follows. Cut the sponge so that any texture "ribs" run perpendicular to the cleaning stroke and with the dimension parallel to the stroke equal to 3.5 in (90mm) and the dimension perpendicular to the stroke equal to 2.75 in (70 mm). When the dry sponge is attached to the cleaning head of the wear tester, the combined weight shall be between 1350 and 1400 g. (Note: Use hook and loop type strips to attach the nylon web of the sponge to the cleaning head.) Place the soiled test panel in the template at 45° to the cleaning stoke. Saturate the sponge and cover the test panel with the cleaning solution. After 30 ±3 sec, clean the test panel using five cycles (one cycle = a stroke in each direction) of the wear tester, then immediately turn the test panel 90° in the template and clean for an additional five cycles. Rinse the panel under a flowing stream of tap water at room temperature and allow to dry fully.

5.3 If determining percent cleanability, measure the L-value of the cleaned surface ($L_c$) and calculate cleanability as shown in the following equation:

$$\text{Cleanability} \qquad (\%) - \frac{L_c - L_s}{L_v - L_s} X\,100 \tag{1}$$

5.4 If determining the total color difference between the virgin and the soiled and cleaned surface, measure the Ĺ, á, and b- values for the cleaned surface ($L_c$, $a_c$, and $b_c$) and calculate delta E as shown in the following equation:

$$E - [\,(\,L)^2 + (\,a)^2 + (\,b)^2]^{1/2} \tag{2}$$

# APPENDIX B

# FIELD TEST REPORT

# FIELD TEST REPORT

Aircraft: P-3
Bureau No.: 148889
Paint System: UNICOAT, Color No. 36375 (painted 8/89)
Treatment: TACSHIELD

Phase 1 (30 Apr 90). Approximately 12 feet of the wing trailing edge directly behind the inboard engines was prepared as follows:

Right side: Scuff-sanded, solvent-wiped twice with methyl ethyl ketone (MEK), masked, and oversprayed with DeSota MIL-C-83286, Color No. 36375 (822X363/910X376).

Left side: Cleaned with B&B Tritech Contact X using terry cloth, rinsed with wash bottle of distilled water, and wiped dry; then, solvent-wiped with MEK.

Phase 2 (7 May 90). Above test areas were checked for 60° gloss (see below), cleaned using MIL-C-85570 Type II (diluted 1:9), rinsed with distilled water, and wiped dry. The area was masked as shown in enclosure (1). TACSHIELD wash applied from a conventional paint spray gun. Since some minor water breaks on the left side indicated a potentially nonuniform film, a second coat of TACSHIELD was applied. Only one coat was required on the right side. Gloss readings after the coating dried as shown below. The marked areas showed some seepage of the TACSHIELD where tape was overlapped.

| | Gloss prior | Gloss after treatment |
|---|---|---|
| Right side (Fresh MIL-C-83286 Color No. 36375) | 0.9 to 1.4 | 1.2 to 1.4 |
| Left side (UNICOAT cleaned with Contact X) | 4.7 to 5.4 | 22 to 27 |

Phase 3 (30 May 90). Following a 3-week deployment and a normal exterior wash by the contractor wash rack crew, the test areas were inspected and gloss readings and photographs were taken. On the UNICOAT side, both treated and untreated areas were relatively free of exhaust soil; but in the small exhaust track itself, the treated area was somewhat cleaner. On the MIL-C-83286 side, treated areas were clean and untreated areas had various amounts of uncleaned exhaust soil, depending on the proximity to the exhaust track; in the actual exhaust track, the treated areas showed some exhaust soil, but the untreated areas showed heavy exhaust deposits. Treated and untreated test areas were then cleaned by hand using a pump spray bottle to dispense MIL-C-85570 Type II cleaner (10% dilution) onto the surface and using a CCC-C-46 Class 7 wiping cloth to wipe dry. Areas were then reinspected and gloss readings and photographs were taken. Little change occurred on the UNICOAT side, but on the MIL-C-83286 side, treated areas in the actual exhaust track were cleanable with some rubbing, while untreated areas appeared to have trapped soil permanently. Gloss readings are shown below:

| | Gloss prior | Gloss after hand wash |
|---|---|---|
| Right side (Fresh MIL-C-83286 Color No. 36375) | 0.9 (treated)<br>0.7 untreated) | 1.2 (treated)<br>0.7 (untreated) |
| Left side (UNICOAT cleaned with Contact X) | 14 (treated)<br>5.3 (untreated) | 24.8 (treated)<br>9.6 (untreated) |

After rinsing with distilled water and wiping dry, the gloss of all areas tended to increase.

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